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ABSTRACT

The declining U.S. student interest in science and U.S. students' poorer performance on standardized tests as compared to their counterparts in other developed nations raise serious concerns over the future of the sciences in the United States. After reviewing the available data, the staff and board of Research Corporation set as one of its major goals to increase the flow of young people into the sciences with programs related to the corporation's expertise. The partnerships which evolved from this goal combine college research with the opportunity for high school teachers to participate in research in many areas of science and invigorate their high school teaching as a result of their experiences. In early 1988, 33 awards were granted in Arizona, California, and New Mexico. Two conferences were organized to facilitate this program. Summaries of the summer experiences and the findings of each conference are the topics of this report. Lists of conference participants, awards, and guidelines for the High School-College Research Partnerships appear in the appendices. (CW)

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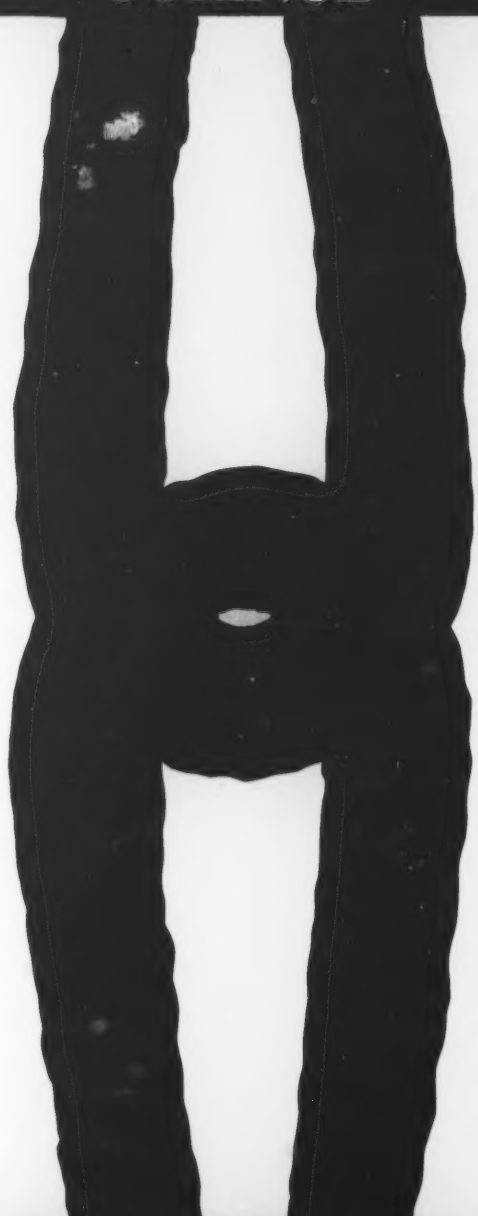

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## HIGH SCHOOL - COLLEGE RESEARCH PARTNERSHIPS

A RESEARCH CORPORATION REPORT

2

# High School-College Research Partnerships

A Report on the 1988 Grants and Conferences

Sponsored by

Research Corporation

# Foreword

The declining student interest in science and American students' substantially poorer performance on standardized tests as compared to that of their counterparts in other developed countries raise serious concerns over the future of the sciences in this country. A number of reasons for the poor test results have been suggested, but no simple solutions are apparent. The problems are so complex, and the needs so great, that many and varied approaches seem warranted.

After reviewing the available data, the staff and board of directors of Research Corporation set as one of the foundation's major goals:

> . . . to increase the flow of young people into the sciences with programs that are appropriate to the foundation's interests and expertise.

Research Corporation's High School-College Research Partnerships evolved from this mandate. The Partnerships combine college research, an area in which the foundation has had years of experience, with the opportunity for high school teachers to participate in research in chemistry, physics, or astronomy—in most cases for the first time. The partnerships promise to invigorate and enrich high school science teaching in a special way.

Early in 1988 some 33 awards were granted under this program in the states of Arizona, California, and New Mexico. In the fall of 1988 the grantees, both college mentors and high school teachers, were invited to join foundation representatives and recognized authorities in science education for a one-day conference. Two regional conferences were organized and carried out by Research Corporation staff to evaluate the effectiveness of program guidelines, solicit the input of participants, and assess future opportunities.

Summaries of the summer experiences and of the findings of each conference are the topics of this report. Lists of conference participants, awards, and guidelines for the High School-College Research Partnerships appear in the appendices.

*Brian Andreen, Grants Program Coordinator*
*Research Corporation*

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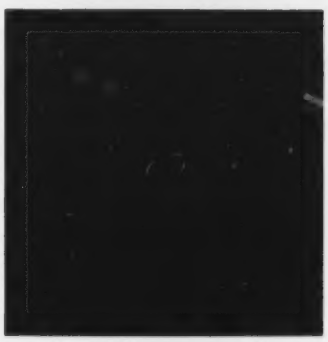

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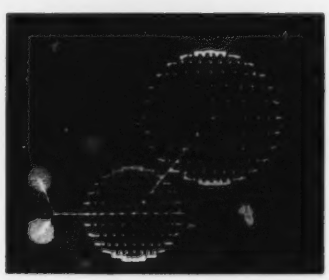

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# *Illustrated Highlights: High School-College Research Partnerships*

**Scanning Tunneling Microscopy**

Two European scientists received the 1986 Nobel prize in physics for the discovery of scanning tunneling microscopy. It was especially timely, therefore, that two of the partnerships featured experiments in which the scanning tunneling microscope played a major role.

***Lynn Schultz, Chandler Senior High School, Chandler, Ariz.***
***Mentor - Stuart Lindsay, Arizona State University***

Lynn Schultz, who did research with the scanning tunneling microscope, remembers his first day working with physicist Stuart Lindsay of Arizona State University. "I was walking down the hallway toward the laboratory," he says. "Dr. Lindsay came running toward me excitedly, saying, 'Look at this, look at this!' as he pointed to some photos in his hand." The photos revealed the structure of DNA and had been made with Lindsay's scanning tunneling microscope, a revolutionary technique for viewing molecular structures. Before he'd even reached the lab, Lynn Schultz had experienced the excitement of research.

Not only did Schultz take this excitement back to his students, he also took a model of Lindsay's microscope that he had made, one of the first of its kind to be used in a high school classroom.

Creating such a tangible, practical product from the partnership experience is quite an achievement. But Schultz sees his microscope as a secondary, short-term benefit. More important, he says, is the ongoing relationship he has formed with Lindsay and the university. He remains involved with the research and has taken his students to the lab. Another benefit of the partnership, he says, is that the hands-on research experience gives the teacher a degree of credibility in the eyes of the students that a teacher wouldn't otherwise have.

***Linda Huetinck, Glendora High School, Glendora, Calif.***
***Mentor - R. Stanley Williams, University of California, Los Angeles***

In another project involving scanning tunneling microscopy, Linda Huetinck studied metals and semiconductors with R. Stanley Williams at UCLA. Huetinck says she learned a great deal about methods of inquiry and problem solving.

"The weekly high point was a group meeting. I was included in a group of 12 Ph.D. candidates gathered to hear a presentation by one of them on their latest research findings. Viewing the inquiry method in action led me to a deeper understanding of the difficulties and fascination of research.

*Chromium complexes that break down when exposed to light were the topics of the research partnership between John Rund (left), University of Arizona chemistry department, and physics and chemistry teacher David Lawrence Byrum of Tucson's Flowing Wells Public Schools. The goal: accounting for the fate of absorbed photons. No stranger to the challenges of science and education, Byrum won the 1987 Presidential Award for Excellence in Science Teaching.*

"Of particular interest to me were the discussions about why an experiment didn't work or why the equipment malfunctioned. I could see the necessity of the problem-solving skills that I try to instill in my students," Huetinck concludes.

Williams and Huetinck plan to bring high school physics students to UCLA to tour a professional research laboratory.

### Biological Chemistry

***Richard Weld, Mayfield Senior School, Pasadena***
***Mentor - Chris Craney, Occidental College, Los Angeles***

Enzymes are a rapidly evolving tool for synthesizing molecules of biological importance. One of the goals of this summer partnership was to synthesize a highly radioactive form of NADP, a cofactor used for biosynthesis. The NADP will be used to study important reactions of key enzymes found in important reactions of human blood cells.

Chris Craney, an associate professor of chemistry and biochemistry, says one of the high points of his involvement with the High School-College Research Partnerships program was attending the Los Angeles conference. He calls the conference discussions "some of the best I've ever been a part of."

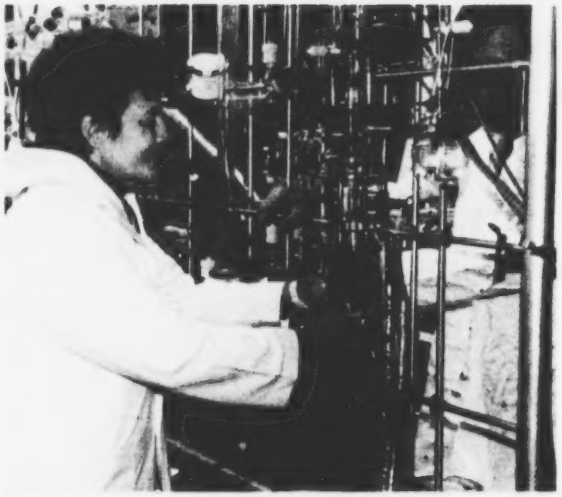
"We got to hear a whole lot of other perspectives," Craney says. "I don't often get the chance to see the problems that fellow chemistry professors and high school teachers experience." A critical task for the science community, he says, "is to explore ways that we might be able to continue this kind of dialogue."

***K. Elaine Miller, Flintridge Prep School and Glendale College, Calif.***
***Mentor - Donald Paulson, California State University, Los Angeles***

K. Elaine Miller and Don Paulson studied metallo-sulfur complexes as models for electron-transfer proteins. Metallo-sulfur compounds are excellent models for the iron-sulfur proteins, compounds which are ubiquitous in nature. Their work could lead to new insights into how electrons are transported within living organisms by these chemicals.

Paulson, a chemistry professor, is a university faculty member with close ties to the secondary school teaching community. He has directed a program under a National Science Foundation education grant to acquaint elementary school teachers with research techniques, and he has given numerous workshops on science demonstrations for senior and junior high school teachers.

"Direct involvement in research is an eye-opening experience for high school teachers," Paulson says, "primarily because it shatters the illusion that everything you try in the lab works right the first time."



*Metal vapor synthesis can produce many complexes that common inorganic chemistry cannot. Partners Bonnie Thompson, a chemistry teacher at Tolleson Union High School in Arizona, and inorganic chemist Robert Zoellner of Northern Arizona University spent last summer synthesizing nickel and iron complexes containing ammonia and amine ligands.*

*Seeing is believing—or perhaps understanding. A research partnership between chemist Trina Valencich (left), California State, and Victoria Macalalad-Bragin of Mayfield Senior School produced computer-generated replications of alkali metal atoms colliding with methyl iodide (see example on page 14). Undergraduate Jeffrey Lopez is at right.*

***Bruce Barichievich, El Camino High School, South San Francisco***
***Mentor - F. Ann Walker, San Francisco State University***

A group of iron complexes, the tetraphenylporphyrins, offer promise as models for heme proteins. Heme proteins play a vital role in the process by which blood transports oxygen throughout the

body and gets rid of carbon dioxide. These synthetic porphyrins are much easier to synthesize than the more complex forms that occur in nature, and they may help to understand important issues concerning the flexibility of heme proteins.

With F. Ann Walker, chemistry teacher Bruce Barichievich analyzed the properties of these porphyrins. The painstaking work made its way into the classroom in a much broader sense.

"Students respond to real events," Barichievich says. "If you can in the course of your class discussion say, 'Oh, by the way, last summer I was involved in this same kind of problem...you'll have the kids in your hand." By drawing from personal experience, he says, "you assure the students that this guy's for real." A further benefit Barichievich mentions is that the hands-on experience with apparatus in the laboratory "explained so clearly those scientific concepts I'd been trying to get across in class."

*The behavior of a metal ion in solution may depend on how many species bind to the ion and how strongly they bind. Partners Herbert Silber and Robert Montoya investigated complexation reactions in mixed solvents as part of their project. Montoya is shown here with his students.*

### Chemistry and Materials

***Robert Lee Montoya, Yerba Buena High School, San Jose***
***Mentor - Herbert Silber, San Jose State University***

Studies of the degree of complexation and the equilibrium constants of metal complexes can help to understand the behavior of the metal ion. Since these complexes are often brightly colored, they have distinctive characteristics that can be measured from the spectra.

Chemistry teacher Robert Montoya spent his summer analyzing chemical complexation reactions with Herbert Silber. A major benefit of the experience, he says, was being able to make his textbooks come alive.

"Students are used to seeing data tables in their textbooks," he says, "but working in the laboratory helped me explain to my students how certain data is generated by using specific equipment." Montoya, who won the American Chemical Society's 1988 Western Regional Award in High School Chemistry Teaching, says the experience at the university has become a valuable source of information that he and his students can continue to tap. For example, Montoya often gives his students Silber's name as a willing resource person for science projects and other activities.

***Sharon Caple, Tuba City High School, Tuba City, Ariz.***
***Mentor - Gerald Caple, Northern Arizona University***

Organic semiconductors hold promise as electrochemical detectors. Molecules such as glucose, diamines, or dopamines, which are not easily detected by conventional means, may give new insights into diseases such as diabetes, cancer, and Parkinson's and Alzheimer's diseases. Once proof of principle is established, it should be possible to miniaturize the semiconductor detectors for in vivo monitoring of body function.

Sharon Caple, a teacher on the Navajo Indian reservation, worked in partnership with her husband last summer on organic semiconductor-based biosensors. Mrs. Caple says the research, which involved studying the conductivity of different electrodes in different solutions, was particularly useful in highlighting the problems that commonly occur in research and how they are solved.

One of Mrs. Caple's students joined her in the lab and will present a poster paper on the research at a meeting of the Society for the Advancement of Chicanos and Native Americans in Science (to be held in 1989 at San Jose State University).

***William Layton, Palisades High School, Pacific Palisades, Calif.***
***Mentor - David Goodstein, California Institute of Technology***

The discovery that some materials become superconducting at much higher temperatures than ever thought possible is one of the most exciting and potentially useful scientific discoveries ever made. It could bring a revolution in the electronics (computers) and electrical power industries. William Layton worked as a member of a research team studying crystal growth techniques that could

lead to a better understanding of high temperature superconductors.

"The best part of the experience was being able to take advantage of the Caltech campus to increase my knowledge of physics," Layton says. "Whenever I had questions or problems I could always find someone who would gladly help me. When I introduced myself as a high school teacher, it seemed as though a magic word had been spoken and I received no end of assistance."

## Astronomy

***Jeffrey Lockwood, Sahuaro High School, Tucson***
***Mentor - Donald W. McCarthy, Jr., University of Arizona***

Physics and astronomy teacher Jeff Lockwood spent his summer with Donald McCarthy, Jr., an infrared astronomer at University of Arizona's Steward Observatory. With McCarthy, Lockwood was able to use one of the world's largest telescopes, the Multiple Mirror Telescope at the Mount Hopkins observatory, south of Tucson.

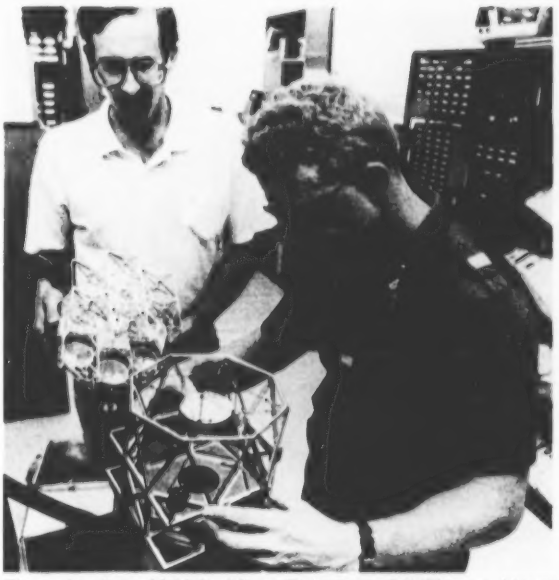
Lockwood and McCarthy searched for objects that eluded astronomers and their technologies until very recently. These new objects in the solar system are larger than Jupiter but less massive than stars and are detected using infrared wavelengths.

The search involved optimizing the telescope's performance by compensating for atmospheric turbulence. This required continual monitoring, adjusting, and fixing of the telescope's equipment.

Some of Lockwood's more harrowing experiences occurred when the telescope didn't work properly and he feared his handiwork was responsible. It wasn't, Lockwood says, though he remembers that "being trusted the way I was could be very scary." Lockwood's research experience was especially timely as astronomers seek to build several new and larger telescopes.

Bringing the research into the classroom can take a creative turn. Lockwood took about 1,000 pages of raw data from McCarthy's desk that had not been analyzed and, a few months into the semester, asked his junior and senior high astronomy students to decipher the data without detailed instructions. "Here it is—do something with it," Lockwood told his students. "I wanted to give them a sense of what I was getting when entering the realm of the unknown," Lockwood says.

Lockwood's students will write a rough paper on the results of their data analysis and present it to McCarthy, who will visit the class and assess the students' work. "I'm modeling this project as closely as possible to the actual research experience," Lockwood says. And, by giving his students raw data, Lockwood is trying to show them the excitement of even small discoveries.



*The six-mirror Multiple Mirror Telescope (MMT) atop Mount Hopkins in southeastern Arizona served as a laboratory for Tucson astronomy teacher Jeffrey Lockwood (left) and UA astronomer Donald McCarthy, Jr., (both holding MMT models). Lockwood has brought his research into the classroom: his students are analyzing raw astronomical data and are receiving feedback from Dr. McCarthy.*

Lockwood's ongoing involvement with astronomy research since last summer has been intense. He recently returned from a meeting of the American Astronomical Society in Boston, a trip funded by his Research Corporation grant. The poster paper he presented there featured his grant research.

***Virginia Esmond-Badger, Gilroy Unified School District***
***Mentor - William Bruce Weaver, Monterey Institute for Research in Astronomy***

Virginia Esmond-Badger, a former science teacher who now serves as science resource person in her school district, spent her summer with William Bruce Weaver at the Monterey Institute for Research in Astronomy, an independent, private observatory. Much of her time was spent in the lab analyzing computer data to locate bright infrared objects in the sky. These measurements follow up on new objects discovered by the Infrared Astronomy Satellite in an unexpected region of space.

"I remember the first time I went up to the Monterey Observatory," Esmond-Badger says. "I was driving there with one of my students on a clear spring night. As we drove around the bend, there it was, standing on top of the hill, just beautiful—and very inspiring." Esmond continues the data reduction work from last summer "every chance I get," she says.

This team included a third partner—one of Esmond-Badger's star students, Paul Tanaka. The same student who drove with her to the observatory that first evening regularly accompanied his teacher to the laboratory.

***Tucker Hiatt, San Francisco University High School, San Francisco***
***Mentor - Stuart Bowyer, University of California, Berkeley***

Astronomy and physics teacher Tucker Hiatt spent last summer searching for extraterrestrial intelligence under the guidance of Stuart Bowyer of the University of California, Berkeley. Hiatt participated on the Berkeley Piggyback Search for Extraterrestrial Intelligence Radio Emissions from Nearby Developed Intelligent Populations (SERENDIP II). An example of scientific cooperation, SERENDIP gathers data unobtrusively on the same radio telescope used for conventional research.

"I'm still very active with the research," says Hiatt, who has given presentations on the work to parents, teachers, and students and regularly visits the lab researchers. Recently his high school financed his trip to an international meeting of The Planetary Society in Toronto, where he discussed his SERENDIP research. He has also helped write scientific papers on it.

Of his SERENDIP partnership, Hiatt writes, "the best indicator of summer success for any grant recipient would be the recipient's consequent life expectancy as a teacher. It is precisely *this* kind of opportunity that helps make me swear that I'll stick with science teaching despite the obvious allure of other science professions."

*Synthesized peptides may make possible new miracle drugs that relieve pain, treat diabetes, and prevent premature birth. In one Research Corporation-sponsored partnership, University of Arizona chemist Victor Hruby and Tucson High School chemistry teacher Amanda Walton created peptides that act like the body's own neural peptides which send chemical messages between the brain and body organs.*

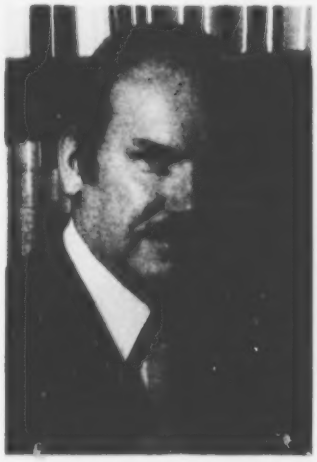
*The war against pain and illness was also waged by partners Sheng Hsien Lin (left) of Arizona State University and Grace Sundling of Phoenix Christian High School. Using nuclear magnetic resonance instruments, the pair investigated molecular mechanisms of anesthesia.*

# *Enriching Science Teaching Through Research*

John P. Schaefer, President, Research Corporation*

Research Corporation is one of the country's first foundations, created in 1912 just a few months after the Carnegie Corporation. The man on the street has probably never heard of us, but we are well known in the scientific community, where we have made grants totaling almost a hundred million dollars to support basic research.

We also work with universities to evaluate their research efforts, identifying interesting and practical ideas and patenting and commercializing those ideas on the universities' behalf. These efforts have brought into public use such inventions as the synthesis of vitamins A, $B_1$ and $B_{12}$, the heart-lung machine, cortisone, hybrid seed corn, the maser-laser concept, and a whole spectrum of important pharmaceuticals.



In fact, Research Corporation got started with the invention of the electrostatic precipitator, which is used in smokestacks to clean up the air. The precipitator was the basis of a highly successful business that became our endowment when it was sold to the public. Our invention administration program has historically generated income that was shared between the university and Research Corporation. Our share has gone back to you, the science establishment, as grants to support more research. This use of inventions from research to fuel further progress has been called the Cottrell cycle after our founder, Frederick Gardner Cottrell, who invented the electrostatic precipitator.

Research Corporation has been a significant granting agency from the start. Our first truly important recipient was Robert Goddard, the father of rocketry, who was conducting liquid-fuel rocket experiments in the 1920s. In the 1930s Ernest Lawrence's cyclotron and the Van de Graaff generator were developed through Research Corporation grants. And 16 or 17 Nobel prize winners in chemistry and physics obtained their first research support from us. Traditionally we have focused on funding research in universities, but in recent years we have explored alternative ways to bolster science education. Because Research Corporation is a relatively small foundation, providing between $3 million and $5 million a year for basic research, it must use a rifle rather than a shotgun approach in advancing science.

### Science Majors Diminish

A matter of increasing concern to the scientific community is the nature and quality of science instruction in the United States. Last year over 60 percent of the Ph.D.'s granted in physics in this country went to foreign nationals; in chemistry the figure is approaching 50 percent. That may not be of nationalistic concern, but it is of concern for the health of our science establishment. The numbers of chemistry and physics majors at our leading universities have dropped by half over the past decade, although they have remained stable in the top liberal arts colleges.

The American Chemical Society Committee on Professional Training reports a decline of 15 percent in the number of undergraduate chemistry degrees. This mirrors a decline in the number of high school students that will continue well into the next decade. At the same time, all projections show an increasing need for scientists and engineers. Retirements in the industrial, academic, and government sectors will accelerate. Medical schools are seriously concerned over the decline and quality of medical school applicants. This trend must be reversed if our technology-based society is to compete in a new world economy.

One hears many complaints about the quality of science education in our high schools and secondary schools. If you can't train teachers who are enthusiastic about their subjects, you can hardly

**John P. Schaefer is also chairman of the board of Research Corporation Technologies, Inc., a nonprofit sister organization of Research Corporation. A former president of the University of Arizona, Dr. Schaefer serves on the governing bodies of a number of international, national, and local scientific, educational, and business organizations.*

expect elementary, junior high school, and high school students to be fired up about the prospect of science as a career. You have simply contributed to a downward spiral, and we are very concerned about that.

Most of the programs in this country that deal with science are directed toward funding specific projects. None are focused on how we can get the best out of our high school teachers; how we can keep them intellectually stimulated and make them part of a network. These are problems we are trying to address as a foundation.

The success of Sputnik in the 1960s sparked controversy in the United States about the state of science education. Agencies like the National Science Foundation poured lots of money into science education by creating summer institutes. High school teachers and college and university scientists participated in summer programs ranging from straight lectures to active involvement in research. But Congress became critical of the program eight or ten years later, charging it had created institute junkies. The term referred to high school teachers who supposedly went from one summer institute to the next without providing any real feedback to the educational system.

As a university faculty member I participated in that program and had a very different impression. We had some excellent high school teachers working in our laboratories who were able to contribute to ongoing research programs. More importantly, these science teachers were enthusiastic about science, and in many cases their zeal made them better teachers. Today Research Corporation is working to revive this relationship between the high school and college-level teaching communities through its High School-College Research Partnerships program.

As we approach the next decade, one of our greatest challenges will be maintaining a dynamic environment for our science educators that will energize both them and their students. This will require continual feedback among ourselves, the purpose of our meeting here today.

## Introduction: Glenn A. Crosby

Dr. Glenn A. Crosby of Washington State University has made many contributions to research, both in this country and abroad. His work has been supported by the National Science Foundation and the Department of Energy, and he is internationally recognized for his research in the field of photophysics and photochemistry of transition-metal complexes.

At the collegiate level Dr. Crosby has made numerous contributions to chemical education. He has served as chairman of the American Chemical Society's Division of Chemical Education, and is the source of such innovations as the Perspective Series and the State of the Art Symposia Series.

Before moving to Washington State as professor of chemistry and chemical physics, Dr. Crosby spent ten years as a faculty member at the University of New Mexico. He has lectured abroad as a Fulbright fellow and Humboldt awardee.

Glenn's contributions go beyond the collegiate level and into the high schools. Every year he meets with hundreds of Washington State high school students, encouraging them to take advantage of educational opportunities.

Many of his efforts have been collaborations with his wife, Jane. They have a unique partnership; indeed, a picture of them together appears on the cover of the September 1985 *Journal of Chemical Education*. The photo shows them accepting Glenn's ACS Award in Chemical Education. With Jane, Glenn has directed the Cougar Summer Science Camp for 150 eighth-, ninth-, and tenth-graders every summer since 1983.

Dr. Crosby has been recognized on his own campus and nationally, receiving four major national awards for his teaching and research abilities. He served on Research Corporation's Grants Advisory Committee for seven years. There are few more qualified to tell us how we can rebuild our educational infrastructure.

# *Science Education at the Interface: Dissolving the Boundaries*

Glenn A. Crosby, Professor of Chemistry and Chemical Physics
Washington State University

Since 1982 many reports have appeared decrying the lack of emphasis on science education in our nation's schools. The pivotal publication, *A Nation at Risk*,[1] was followed by many others; a most unusual one was *Educating Americans for the Twenty-First Century*.[2] These accounts, augmented by several more such as the Carnegie report and the report of the Holmes group,[3] focus on the deteriorating quality of our educational systems not only in the public schools but in the colleges and universities also. Of primary concern are science literacy, science education, and education in general.

The documents focusing on education have been supplemented more recently by studies on the declining competitive stance of the United States vis-a-vis the rest of the world, particularly the declining capacity of our work force to measure up to the problems and challenges before it.[4] My thesis is that a significant component of the nation's educational difficulties can be traced to barriers between different systems that impede, unnecessarily, the passage of students from one type of institution to another.

To discuss this subject I have chosen a chemical theme, Science Education at the Interface: Dissolving the Boundaries. It is no secret that chemistry at interfaces is very important chemistry. In fact, some of the most exciting things in the world of chemistry are occurring at interfaces. Catalysis occurs at an interface; membranes constitute interfaces between identifiable components; a cell wall forms interfaces. There are also educational interfaces, and if we do not do something about them, we are going to continue along a route that will eventually bring us to the brink of educational, and hence economic, disaster.

## Interfaces Between Disciplines

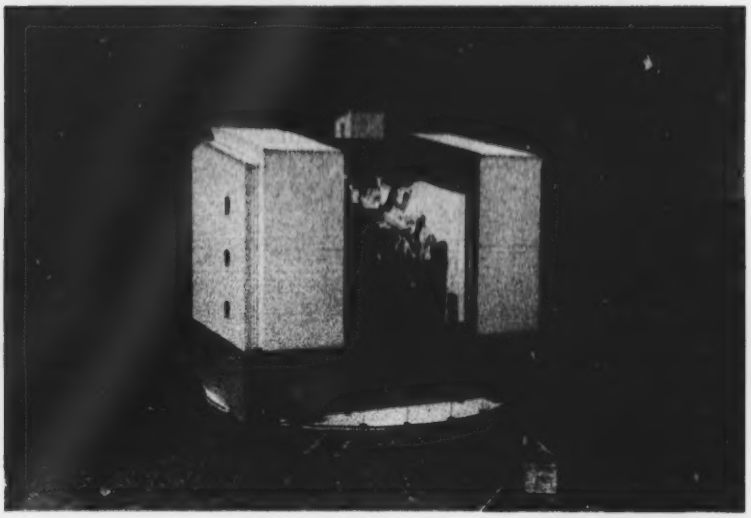
The most obvious barriers in academe occur at the interfaces between disciplines. The chemists no longer talk to the physicists, the physicists no longer talk to the mathematicians, and the students talk to none of them. Courses do not mesh, and students become bewildered as they traverse from one discipline to another without any sense of continuity.

Within universities autonomous units have become super strong compared with the structure of the whole. The universities are comprised of isolated fiefdoms; they are not functioning as coherent entities for the benefit of students. These interfaces must be dissolved or at least substantially modified to improve learning. To attack this problem we must promote communication among scientists of disparate disciplines for the ultimate benefit of students.

## Interfaces: Two- and Four-Year

Another important interface is the boundary that exists between colleges or universities and community colleges. In some locales there is an almost impenetrable barrier between these systems. For us in the sciences this is very serious. Recall that more than 50 percent of the freshman chemistry in the United States is taught in community colleges, and that community colleges are the primary route into higher education for minority students and students from low-income families. This barrier is not helping science.

The articulation between schools is so poor that community college students who transfer to four-year institutions are frequently delayed in their progress by as much as a year or more. Through such inconveniences as programs that do not mesh, or through incorrect and inappropriate advising, students are caught in difficult transfer problems. They often arrive at a university intending to major in a science such as chemistry without even having spoken with anyone in a chemistry department before enrolling. They do not learn of the problems they will encounter, the special requirements of the discipline, until they are well along in the program.



*The Multiple Mirror Telescope (MMT) in southeastern Arizona, with six round mirrors in a hexagonal mount, is one of the world's largest telescopes. Jointly operated by the Smithsonian Institution and the University of Arizona, the MMT was the site of research by Arizona astronomy teachers Jeffrey Lockwood and Donald McCarthy, Jr.* *(See page 7 for more information.)*

There is very little done to prevent culture shock when students change institutions. A psychic trauma often occurs, especially when a student transfers from a local school with small classes and personalized attention to a large research institution. Many students wander aimlessly, not because they are stupid, but because they are uninformed and do not know how to obtain pertinent advice. Such barriers to educational progress must be lowered if we are going to smooth the transitions from community colleges to four-year institutions. It is incumbent upon these systems to synchronize their efforts.

I am not speaking of communication among high-level administrators, recruiters, and admissions officers. I am talking about communication and discussion at the level of the instructors themselves, where the educational action is. Only in this way can these community college-university transfer problems be alleviated.

**Interfaces: High Schools and Colleges**

The third interface that is very, very important to all of us is that between the high school and college systems. There is a huge barrier separating these two components of education. For the student there is, correspondingly, an abrupt transition. It is a unique experience to transfer from a high school to a college or university; things are never again the same. Many students suffer because they do not have street smarts, the information they need to survive academically in the college or university.

In high school, students are monitored closely—the teachers know their names, their habits, their handwriting, and their attitudes. But in many four-year institutions the environment is radically different. Students are no longer personally known, and sometimes not even recognized, by their instructors. Some students spend two or three years at a university and never talk with a professor. They experience cultural dislocation. For many of them it is too much. They become dismayed, disappointed, frustrated, and defeated. A student at 19 or 20 sees his or her dreams dissolving in a situation that appears to be out of control. These are the devastating results of the enormous barriers between educational systems. Somehow the nation must do something about them.

To begin to attack these pervasive and pandemic problems, the college and university faculties must appreciate the many problems that high school teachers face. Likewise the high school teacher must recognize that university professors have different pressures on them. We need to understand each other's problems if we are going to help our students.

For example, college and university faculties should explore with secondary school teachers mechanisms for exposing high school students to the environment of higher education before they irreversibly enter the system. There should be more student visits to university and industrial laboratories; there should be more career days, more advising sessions, so students can acquire some sense of what lies ahead. There should be more visits to high schools by university professors. There should be much more direct information transfer between those who teach the first-year college courses and the high school teachers who prepare students for them.

What will be expected from these students when they arrive on campus? In the case of freshman chemistry, what do we expect students to know before they walk into the university classroom? How will they be treated? Will their homework be graded? The high school teacher needs such information to prepare students for that big step from the high school to the university.

Improvement in the lines of communication between high school teachers and college and community college faculties is occurring through such initiatives as Research Corporation's High School-College Research Partnerships program. It is a small contribution toward the solution of an enormous problem.

There are other positive developments. A number of years ago the American Chemical Society (ACS) established a high school office, and a high school component was incorporated into the national meetings. Now as many as 150 to 200 high school teachers attend national ACS meetings, and the ACS Division of Chemical Education has expanded its biennial conferences to include high school teachers. Fully 200 of the 800 attendees at those conferences teach in high schools.

Moreover, the Division of Chemical Education has expanded its *Journal of Chemical Education* to include a high school component that is integrated with the rest of the journal. These have been big steps forward. They show that there are things that can be done to improve communication between secondary and postsecondary faculties.

### Interfaces: Elementary and Secondary

There is another educational interface that must be dissolved, or at least mitigated: the interface between the elementary schools and the high schools. When I ask a high school teacher what the biggest problem in the classroom is, he or she often says, "Those elementary school teachers just don't teach anything." My colleagues at the university utter this same complaint about the high school teachers, and I suppose the elementary school teachers say the same thing about the kindergarten teachers. These are the kinds of debilitating remarks that lead us nowhere. If secondary school teachers want better students who are excited about science and eager to enroll in their science classes, they must share their expertise with their colleagues in the elementary schools.

The American Chemical Society has a high school office; it also recently established a pre-high school office. These initiatives are highly commendable, but they are not sufficient. Until those of us who are in the field—in particular those of us teaching freshmen at colleges and universities—realize that we have an obligation to know what is happening in the public schools, to understand the problems faced by secondary and elementary teachers, and to help smooth the transition for students from one system to the other, we will not have the kind of educational continuum this nation desperately needs.

### Educating the Nonscience Major

Another serious national issue is the education of the nonscientist. A few years ago the National Academy of Sciences issued a book that focuses on the problems of educating the nonspecialist.[5] The publication is a scathing denunciation of what passes for a general science education in colleges and universities.

The problem of informing the nonscientist is important because nonscientists help shape national policy. They may become lawyers, congressmen, and staff members of congressional committees, for example, who formulate budgets and make appropriations. Their lack of knowledge about science and technology and their respective roles in the economy are very serious issues that universities have largely ignored.

In reality the nonscience majors are much more important than the science majors, because there are so many more of them. We must begin to inform them of the role of science in the modern world. We must develop upper-division courses for the nonscience major in order to promote scientific literacy.

The most effective barrier to this essential development is not the university administration; it

*The spectacular view from the roof of the MMT is enjoyed by astronomer McCarthy and mechanical engineer Dan Blanco.*

is not financial constraints; it is not lack of latent interest on the part of students. The greatest barrier hindering the development of courses for the nonspecialist is the lack of qualified faculty. Science and engineering faculties are comprised of specialists. All professors have a Ph.D. in a specific discipline, but most have failed to broaden their educations enough to teach science in a palatable way to nonspecialists that is enjoyable, informative, and conducive to better citizenship. University faculties must be developed to carry out that formidable assignment.

### Educating the Public

Those of us engaged in scientific research have an additional serious communication problem. We have not done a very good job of explaining to the general public the importance of science, explaining what the public's role and stake in scientific endeavors really are.

The American people have always assumed a strange love/hate posture toward education. In the history of education the vicissitudes of appreciation and support by the public have exhibited enormous amplitude. In a matter of a few years, education can drop from No. 1 concern to No. 15.

In order to keep the support at some respectable level, educators must take an active part in promoting in the public a sustaining attitude toward the educational enterprise. This means that educators, both in the high schools and colleges, must assume obligations to communicate with the public. We must learn, for instance, to address school boards and argue our cause. If necessary we must run for office.

We must learn to go before the parent-teacher organizations and tell parents gently what the consequences are when one lacks equipment in laboratories. They must learn how difficult it is, for instance, to teach high school chemistry without beakers. The public-support problem is that serious in many school districts, particularly those in rural areas.

Educators must assume active roles to promote education by speaking before groups such as the Kiwanis, Lions, Rotary, and Exchange clubs. The memberships of these organizations are made up of influential people who really want information. They need to listen to someone they know, someone who can tell them from daily experience what the problems really are. They need to understand these educational problems at the level of individual daily action.

In addition to the general problem of an uninformed citizenry, the United States has the additional problem of the underrepresented groups in science becoming progressively more underrepresented. Somehow we have failed to understand and appreciate the reasons for the underrepresentation of women and minorities in science. The talent is there; we just have not developed it.

*An example of the output of a research partnership is this computer simulation of potassium and methyl iodide molecules in collision. It was done by Victoria Macalalad-Bragin of Mayfield Senior School in partnership with Cal State chemist Trina Valencich.*

It is a national scandal, in my opinion, that we are importing our graduate students and postdoctoral fellows from other countries. In a nation of 250 million people, it is shameful that we cannot educate our own citizens to assume the positions in our graduate schools that will take them to the top of the intellectual and economic ladders.

To depend on the importation of intellectual capital in a country as large and developed as ours is a sign of educational failure. We must face that failure. We must understand the current demographic trends and face the attendant problems head-on.

It is not enough for our educators to be worried about these problems. It will take the concern and commitment of every segment of society, including organizations such as Research Corporation, the National Science Foundation, the National Institutes of Health, the parent-teacher organizations, the educational associations, and the service clubs. They must all understand that the nation has a problem. Only when most citizens understand that there is a problem will we have any hope of attacking it in a mature and sensible way.

### Dissolving the Boundaries

There are serious educational barriers in this country, barriers that developed slowly. Some are truly historical. We did not try to construct them; they just grew. Now the nation is beginning to realize that they are genuine impediments to progress and that they must be dissolved. The 21st

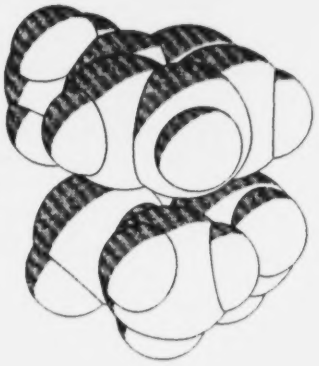
century is 12 years away, which may seem like a long, long time to a teenager, but it is really tomorrow. We do not have much time.

We are all in this endeavor together. Barriers exist that must be surmounted or dissolved or we are never going to establish an educational system that truly benefits students. In retrospect I think this is the key attitude we must adopt. We must ask what is best for the student—not what is best for me, or best for the high school or college, but what is best for the student. If it is best for sixth-grade students for a college professor to give them a science show on Saturday afternoon, that is what the professor should seriously consider doing.

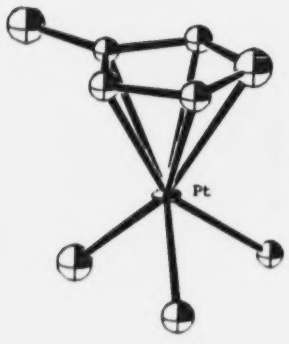
All components of the educational system must start to share expertise and information. Colleges and universities should become convenient resource centers for high school teachers. Not only must university teachers conduct workshops and staff information sessions, they must also be readily available to supply information on a continual basis. The same kind of activities should involve high school teachers with elementary school and middle school teachers. The impact would be significant. The important point is the necessity for us to take a positive stance toward solving the educational problems and to promote information exchange among all segments of education.

Although the tenor of this disquisition is pessimistic, there is room for optimism. In the efforts of Research Corporation I detect a small but important glimmer of hope. It is satisfying to see high school teachers in research laboratories, to see workshops for the benefit of high school teachers, to observe that support is forthcoming for the development of elementary school science curricula. It is pleasing to note that an enlightened attitude is starting to develop. It is especially encouraging to observe that the scientists and engineers are beginning to understand the depth of the nation's educational problems and the roles they must play in resolving them. Although money helps to solve problems, money alone is not enough. It takes compassion, hard work, knowledge, and empathy with the very groups one is trying to help.

Above all we need creative ideas on ways to attack what I consider to be the most serious problem encountered by U.S. science in the last half of this century—the slow, debilitating erosion of its educational infrastructure. Science must turn its attention to the strengthening of its own roots. Without educated people there can be no competitive science.



*Partners M. Patricia Noel and chemist Herbert Kaesz of UCLA studied organometallic chemical vapor deposition of transition metals. Right: molecular model of hydrocarbon-metal complex.*




*Left: projection of carbon and platinum atom-skeleton of organometallic compound. Platinum is deposited from vapors when complex is heated to 120°C in hydrogen atmosphere.*

Notes:

1. *A Nation at Risk: The Imperative for Educational Reform, A Report of the National Commission on Excellence in Education* (Washington, D.C.: U.S. Government Printing Office, 1983).
2. *Educating Americans for the Twenty-First Century, A Report to the American People and the National Science Board,* National Science Board Commission on Precollege Education in Mathematics, Science, and Technology (Washington, D.C.: National Science Foundation, 1983).
3. *A Nation Prepared: Teachers for the Twenty-First Century, A Report of the Task Force on Teaching as a Profession* (Carnegie Forum on Education and the Economy, 1986); *Tomorrow's Teachers: A Report of the Holmes Group* (East Lansing, Michigan: The Holmes Group, 1986).
4. *Economic Competitiveness. Can the U.S. Regain Its Balance? Science* 241(1988):299-322.
5. *Science for the Non-Specialists: The College Years,* Committee on the Federal Role in College Science Education of the Non-Specialist (Washington, D.C.:Commission on Human Resources, National Academy of Sciences Press, 1982).

# *The Liberal Sciences*

Neville J. Woolf, Professor, Astronomy Department
Steward Observatory, University of Arizona

The combination of research and teaching is a revolutionary process. Socrates was killed and both Anaxagoras and Aristotle were forced to leave Athens because their work raised questions about the cultural values, beliefs, and taboos commonly held in their society.

More recently it took a century of chaos before the Copernican model of the Earth revolving around the sun was accepted. Only after Copernicus had demonstrated the role of planet Earth in the physical scheme of thing was it possible to explore questions of origins—the origin of the elements, the origin of the Earth, the origin of all life upon Earth, and the development of life forms from one another.

Similarly it was only after Kepler discovered regularities in the solar system using the Copernican model that Newton demonstrated the laws of mechanics using evidence from astronomy. It is with those laws of mechanics that mankind began to take charge of its destiny.

The principle that nature follows consistent patterns is now generally accepted, though our culture still makes us feel uncomfortable about applying this principle in any social situation. We like to believe that somehow we have a free will independent of the influences upon us, that the poor choose to be poor or that the criminal chooses a path of crime, rather than to recognize that human behavior follows patterns just as nature does.

The application of the principles of natural laws and origins has totally changed our way of thinking, and the change has been evident as recently as the past 50 years. If 50 years ago there had been a natural disaster and you were to ask people about it, most would have said it was an act of God. Today people are more likely to look for earthly causes and sue someone. The prevailing attitude is that not only are there causes and effects, but that we have substantial control of our destiny. In this sense man has taken over a role we formerly thought to be the role of God.

Our problem as educators is to prepare people for a society in which man has taken over these roles and has accepted the principles of natural laws, yet sees science as a kind of magical suspension of those laws. The public often acts as though it can defy cause and effect.

One example is the idea that the United States can maintain current levels of funding for defense and for various other programs and, at the same time, not raise taxes and get rid of the deficit. It brings to mind the legend of Midas, whose touch turned everything to gold, including—much to his dismay—his daughter. Science is not magic. Both gains and losses should be predicted before deciding on a course of action.

Of course we are never certain that the cause follows the effect: the criminal might plead his innocence because when he pulled the trigger he thought there was a chance his gun would not fire. But we would not accept such an argument. In reality we must all live as though the principle of cause and effect were immutable, and we must teach that to our students.

### A Revolution in Thinking

Where does all this fit into our educational scheme? I suggest that we need a total revolution in our thinking. No society has yet evolved where the principle of cause and effect has overridden long-held values and taboos. Lysenko stopped the advance of Russian genetics during Stalin's time.

And today we Americans do not allow evolution to be treated fairly in many schools. We are afraid to demonstrate clear-cut evidence of the evolution of the horse, for example, or the similarities and differences between lemurs, monkeys, the apes, and ourselves. A *Newsweek* poll tells us that more than a century after the publication of Darwin's *Origin of the Species*, 43 percent of Americans say man developed from nonhuman predecessors and 47 percent still don't believe it.

The society that accepts cause and effect most fully has the strongest weapon for its survival. We must begin teaching this principle in elementary

## *Introduction: Neville J. Woolf*

One of the University of Arizona's more distinguished scientists, Dr. Neville J. Woolf is a leader in one of the world's topflight astronomy programs. Dr. Woolf has taught astronomy at the University of Arizona since 1974. He has also served on the faculties of Columbia University, the University of Minnesota, and the University of Texas.

Earlier, Dr. Woolf served as acting director of the University of Arizona's Flandrau Planetarium and director of the Multiple Mirror Telescope on Mount Hopkins, south of Tucson. He is currently the project scientist for the Mount Graham Observatory.

Dr. Woolf has been a Fulbright scholar, a senior postdoctoral fellow with the Goddard Institute for Space Studies, and an Alfred P. Sloan fellow. A native of Great Britain, he received a Ph.D. in astrophysics from Manchester University in 1959. His broad range of interests in astronomy include optical and infrared instrumentation, stellar evolution, and cosmology.

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school long before students reach the universities that lie at the heart of our educational system.

### Culture and Value Systems

Presently we teach science in a technical manner and treat cultural education as an arts topic, but culture is at root a system of making decisions, and decisions are a fundamental aspect in science as well.

There are two things a person can get out of a cultural education. The first is an appreciation for the products of the past. I enjoy reading Plato, listening to Bach, viewing a drawing by Rubens, and reading mystical works from India or Tibet. But I never had a course on any of these works; those who are interested will indeed come to the well.

Appreciation of the products of the past is fine for recreation, but repeated exposure to them is not essential for a sound education. In some senses we are pushing in the wrong direction. Some say those who don't know the past are condemned to relive it. Certainly we don't wish to repeat the holocaust or the Vietnam War. But in looking back we find that we don't learn as much about mistakes from the past as we do about the mental processes of the historians.

The second thing to get from a cultural education is an understanding of the value systems of the past. And these values we most urgently need to reassess. Anthropologists have shown us that societies incorporate a surprisingly varied set of human roles, values, and taboos. Some of these values seem fundamental to us, while others appear irrelevant. Cultural choices are superstitious behavior, results of mental associations that were made before it was understood how to test for statistical significance or how to avoid systematic errors.

It is indeed unwise to walk under a ladder, if only because something might fall down. On the other hand, avoiding the path of a black cat is unnecessary, since cats generally do not enter the scheme of things that can affect our existence. Though some superstitions may rest on valid assumptions of cause and effect, they can also rest on fallacious ideas that have been picked up and retained. As long as we are governed by inappropriate ideas from the past we will be unable to change the future.

Two of our society's fundamental concepts, the value of human interaction and liberty, are diametrically opposed. Human interaction is necessary for survival of the species and of society. But liberty is limited to what one person can do without another objecting; it is a sort of carving out the territory. The implication is clear-cut: Our own liberty will be affected by how our actions affect others. Always the question must be asked, how much liberty can be allowed? We live with a constitution that found a balance that seemed adequate for the 18th century. Decisions for today are still based on that balance without reasonable means of reassessing it.

We have to think of what is needed to get all these ideas across in the classroom. Education has to be a revolutionary process. We have to change our ways of doing things, to focus on the way people learn rather than on systems that operate to ensure their continuance. We have to recognize that the situation we have right here—one person talking to a group of people—is about the most inefficient means of communication at our disposal. Approximately ten percent of what I say will be remembered—if I am lucky. Our entire teach-

*This time-exposed photograph shows star trails reflecting the Earth's rotation. It was taken at the Monterey Institute for Research in Astronomy, where Virginia Esmond-Badger, from a California school district, worked in partnership with resident astronomer William Bruce Weaver. The observatory's 36-inch telescope is shown here peeking above Oliver Observing Station.*

ing system is based on this method of communication although there are other methods that are much better.

**Some Valuable Lessons**

What are the sorts of things that might be worth teaching in a liberal science course? One is the rather simple principle that nature reacts against the changes we try to make. It is a useful thing to start with because it teaches students to think in terms of the equilibriums that exist in nature and the disturbances that naturally occur.

Another extraordinarily useful teaching vehicle is Newtonian mechanics, which provides a clear-cut demonstration of cause and effect. Newtonian theory deals with single causes and effects, however, while the sciences are moving toward complex systems. Physics is interested in cooperative phenomena like those that permit superconductivity; astronomy is interested in complex systems like galaxies and galaxy clusters; biology is moving away from examining organisms to examining ecosystems or even treating the multi-celled organism as a kind of ecosystem. We must make people think in terms of systems and the complexity of their interactions.

Ultimately we must come back to trying to teach people that consequences are something one infers, not from one's desires, but from an analysis of the evidence. I hate to think of the number of papers that I have read in the *Astrophysical Journal* that present a set of results on the one hand and then a set of concluding statements on the other without any obvious connection between them. And the *Astrophysical Journal* is considered to be one of the better scientific journals. We must recognize that our conclusions often arise from precognitive processes in which our emotions may be dominant.

We must accept our animal heritage and understand how it can, and does, manipulate our behavior. A crucial part of education has to be in that area. Only with this understanding can we be free to develop a society that properly balances human needs. That freedom can come only with a proper education in science, and the core of that education has to be a course in the liberal sciences.

# *Inspiration: The Common Thread*

## An Introduction to the Group Discussions

Brian Andreen, Grants Program Coordinator
Research Corporation

You learned earlier in this meeting—if you haven't heard it before—that we have a crisis in this country. Two years ago Research Corporation began a grants program review, and the data gathered in that process convinced our staff and board of directors that the dwindling supply of young scientists was one of the major problems facing science and our society.

As a result the board adopted the following objective in 1987. It represents a major thrust of our grants program.

> ... to increase the flow of young people into the sciences with programs that are appropriate to the foundation's interests and expertise.

One study (commissioned by Research Corporation) of science graduates in the 1950s and 1960s revealed that most had first decided to pursue science careers in junior high school.[1] More recent studies have borne out this finding. While some conversions to science may take place at the collegiate level, intervention at the precollegiate level is necessary to increase the number of new scientists.

There were two other factors that played a role in the development of the High School-College Research Partnerships program. One was concern over the widening gap between science as it is practiced, and science as it is presented in entry-level courses. This is, in part, the age-old debate between content and methodology, but the problem goes deeper. Instrumentation and computers have dramatically changed the way research is done, widening the gap. Many teachers have inadequate preparation in some of the new technologies and are unfamiliar with many leading advances.

The other major problem is the lack of interactions between science educators and research scientists. The research scientist who maintains a broad interest in science education is rare indeed. Most of the interactions between precollegiate teachers and university professors involve people in education departments and those not engaged in current scientific research.

The high school program developed out of these three concerns: the increasing shortages of physical scientists; the widening gap between the practice and presentation of science; and this discontinuity in the scientific community—the absence of regular involvement of research scientists with precollegiate teachers.

We recognize that ours is but one of many desirable and necessary programs to strengthen high school science teaching. ICE (Institute for Chemical Education), the Dreyfus Master Teachers, ISMEE (Institute for Science, Mathematics, and Engineering Education), and various National Science Foundation programs, to mention but a few, are directed to different but important ways of strengthening science education in the secondary schools.

The common thread running through this program—at every level—is inspiration. Research Corporation hopes that direct participation in research will truly excite high school teachers, whatever the form of inquiry may be. These teachers are given the freedom—and the challenge—to work independently, to struggle with the frustrations and spontaneity of research. They are not coddled. And their work has real-world implications that extend beyond the laboratory and into the high school classroom. The experience may ignite a teacher's enthusiasm for scientific research and spark a response in some unsuspecting high school student. Every student thus converted to a science career is a victory for the future of American science.

1. W. Rodman Snelling and Robert F. Boruch, *Science in Liberal Arts Colleges: A Longitudinal Study of 49 Selective Colleges* (New York and London: published for Research Corporation by Columbia University Press, 1972).

# *Group Discussions: Reports and Recommendations*

*Each conference on the High School-College Research Partnerships included a plenary session and breakout discussion groups. The plenary sessions featured distinguished scientists who spoke on issues of importance to contemporary science education.*

*Following these presentations the attendees separated into breakout groups that were given specific assignments. The groups reconvened after lively discussions and provided reports to the entire assembly. This section conveys the substance of the group discussions and final reports. There were many good suggestions for improvement and expansion of the partnerships.*

## Program Goals

### *1. Teacher participation in collaborative research at the cutting edge of science*

All of the high school teachers reported that they had been given both freedom and responsibility as researchers. Most were welcomed as equals, although they spent much of the first year securing the background that joint research required. Most teachers felt that the collaborative aspects of the research would grow during succeeding summers.

Teachers spoke of the excitement of research, which some of them had experienced for the first time. There was also frustration, an inevitable part of almost any research project. A theme reiterated by teacher after teacher was that there is no effective substitute for direct research experience.

Publications and the scientific significance of the research seemed to be of less concern to the teachers than that the work be of a nature that would enable them to make meaningful contributions.

The structure of the partnerships varied greatly. In some there was frequent mentor-teacher contact constructed around a small, tightly-knit research group. For others the partnership revolved around a large group of postdoctoral and graduate students. One partnership was loosely structured so the high school teacher could interact with several research groups making contributions to the subject under study. The high degree of independence and responsibility shown by the high school teachers was praised by a number of mentors.

### *2. To foster long-term collaboration and continuing partnerships*

Most participants felt that at least two summers were necessary to accomplish a reasonable amount of work. There was also evidence, in at least several cases, that the groundwork had been laid for a significant, long-term effort. Several partnerships have established means for keeping in touch throughout the school year.

In practice there are many obstacles to securing long-term relationships with high school teachers. Not the least is the practice in precollegiate edu-

*Clear from the conferences is that HSCRP participants are dedicated, highly committed science educators. Thoughtfulness and eloquence marked the high school teachers' comments on the many issues addressed. The mentors were supportive and receptive to opportunities to expand the impact of the partnerships. And everyone demonstrated a sense of humor.*

cation of short-term, individual summer educational experiences rather than ongoing summer programs. Several high school teachers, while looking forward to a second summer, felt guilty that their colleagues were missing such an opportunity.

Another impediment to securing a long-term collaboration can be geographic distance between teacher and mentor. For this reason local partnerships were strongly supported.

While finances are always a concern, several options for funding long-term partnerships do exist. The federal agencies have in some cases provided support through regular grants. Since a majority of the collegiate mentors do have such funds, this is the most promising source of support. Industry, other foundations, and scientific societies are also potential sources of assistance. As one example, the American Society for Biochemistry and Molecular Biology has supported several high school teachers each summer for the past five years.

***3. Stimulating interest in high school science teaching and attracting more qualified teachers***

There are concerns that high school teachers may find research so attractive after the partnership experience that they will be lured away from high school teaching. The program conducted by the American Society for Biochemistry and Molecular Biology led to two such career changes.

Most of the teachers did not see this as a serious concern, however. It was suggested that the invigorating effects of summer research would perhaps save many teachers from leaving the classroom for industry or full-time research.

Science graduates have historically shunned high school teaching, mostly for economic and professional reasons. The economic penalty to scientists who wish to teach at the precollegiate level can be well documented. Yet experience has shown that using market conditions for each discipline to set teacher salaries is politically impossible.

A summer stipend, as provided by the Research Corporation partnerships, allows a supplement to science teacher income without creating internal dissension. While a reasonable stipend is desirable, the opportunity to become a participant in state-of-the-art research outweighs economic considerations in the minds of most participating high school teachers.

***4. Guiding students towards careers in science***

Although the high school partnerships do not specifically provide for high school students, there should be considerable impetus to involve them.

*"Partnership" means collegiality, equality, and shared experience. For research partners Eric Gregory of Linden High School and Joyce Takahashi Doi of the University of California at Davis, the October Los Angeles conference was a time to catch up.*

As the pool of science students has shrunk, more and more schools have begun to recruit actively. Summer programs are a commonly used tool. Both federal and private sources also fund summer programs for student groups underrepresented in the sciences. Some of the partnerships interacted with high school students supported through these programs, but there was no direct student involvement in most cases. There was, among the high school partners attending the conferences, strong support for the inclusion of high school students.

Obstacles are many. Lack of insurance coverage and the liability issue are of deep concern at some schools. The idea of letting high school students, many with exuberance and impulsive tendencies, loose in a laboratory full of expensive equipment is not attractive to some university mentors. Concern was also voiced over the possibility that the high school teachers might be distracted from the research by their responsibility to their students.

For many teachers the first summer partnership involved too many new responsibilities and uncertainties for a student-teacher relationship to be considered. The second year may be more favorable for direct student involvement, given a better understanding of the opportunities and operation of the partnership.

There are many other benefits that will accrue to the students of the high school teachers. First and foremost, the summer opportunity inspired in most of the teachers a new level of enthusiasm for, and appreciation of, scientific research. Most of the high school teachers brought back to their classrooms new ideas that will be incorporated in their classes, new experiments for their laboratories, and, in some cases, new equipment. Stamped with

*California high school teachers Robin DeKleine (left) and Sister M. Gloria Sturgeon take a break at the Los Angeles conference. For both teachers and mentors the partnerships are enriching experiences that pave the way to new opportunities.*

the mark of authenticity, these teachers have gained a new prestige on the high school campus.

There are many spin-offs from the partnerships that will have a positive impact on the students. Some university mentors and their colleagues have agreed to give lectures to the high school classes. One high school teacher has arranged field trips for classes of physics students to visit the university research laboratory. There are also instances in which the high school science teacher will serve as a mentor to K-8 teachers or work directly with K-8 students.

#### *5. Partnerships—the implicit goal of the awards*

The word partnership denotes a special relationship, one characterized by collegiality, equality, and shared experience. Such a relationship is one of the goals of the Research Corporation grants. An examination of the stated program goals indicates that the flow of benefits are heavily in the direction of the high school teacher. The partnership concept is designed to counterbalance that flow.

As one of the partners so aptly put it, science education is rife with unconnected factions, multiple communities of people who pass like the proverbial ships in the night. Glenn Crosby described the problem another way: the no-man's-land of academic interfaces.

The major success of these grants may be that they have provided a bridge between collegiate research scientists and high school teachers. Major educational initiatives are often staffed either by scientists whose own research activities have waned or by school of education faculty members. The vast majority of scientists remain untouched and out-of-touch with the wellspring from which their students emerge. This is a serious flaw in most science education programs. The scientific research community needs to be involved with precollegiate science education.

At the same time busy, productive research scientists have neither the time nor the inclination to get involved in major programs in teacher education. If there is to be interaction, it must begin on the research scientists' turf. The partnerships offer a way for such interactions to begin.

The development of several viable and growing partnerships is a major consequence of these awards. After just one summer's effort, it is clear that the partnerships awakened in the mentors an interest in precollegiate science education and an appreciation of the opportunities to assist high school teachers through mutually beneficial interaction. The ongoing dialogues that have resulted from the partnerships will help to connect the two science teaching communities.

Not all grants resulted in lasting partnerships. Human nature being what it is, some pairs just did not mesh. More often other commitments or opportunities led to a dissolution of the partnership.

Over 20 of the 33 partnerships are seeking renewal for a second summer. For both the high school teachers and the college or university mentors, the partnerships have been enriching experiences that will pave the way to new opportunities.

### Program Focus

The first year of the high school grants was directed toward support of individual partnerships within the broad goals of the program. Selection was based on professionally viable criteria and standards. The accomplishments of these partnerships and the scientific merit of their research have generally been excellent.

#### *Initial program considerations*

To give some structure to the first year, three aspects of the guidelines were emphasized in the selection of partnerships:

- **Active mentors with ongoing research were deemed essential. This was judged primarily by research publications and grants.**

- **High school teachers selected had solid chemistry or physics backgrounds. Teachers without the requisite training place an added, and in many cases unacceptable, burden upon mentors.**

**• Local collaborations were favored. Long distance collaborations raise obstacles that can weaken the strength and intensity of the partnerships.**

Most participants at the conferences supported these requirements for both mentors and high school teachers. However, they were wary of turning the competition into a numbers game; that is, counting publications for mentors or rejecting teachers who, while not possessing the requisite science training, had gained substantial scientific knowledge informally or in summer institutes.

It was noted during both conferences that while the 1988 participants were highly motivated, there may be many high school teachers who have a greater need to experience the excitement and hands-on involvement of research. These can further be divided into those who have the requisite science background and those who do not. As those who possess the requisite background learn of the experience of their peers and become motivated to seek a partnership, summer research could stimulate renewed enthusiasm and even a transformation in these teachers as well.

The high school teacher with a weak scientific background is another matter. There was a consensus that in most cases a lack of appropriate training would seriously impair ability to function independently or collaboratively. It could dampen a collegiate mentor's enthusiasm to be called upon to teach fundamental chemistry or physics. The high school teacher could, in turn, become frustrated. Science will be better served if such individuals complete the fundamental courses that a comprehension of the subject demands.

***Targeted populations***

High schools and high school science teachers differ widely in their characteristics. The schools represented in the High School-College Research Partnerships have ranged widely in enrollment (80 to 4,300); socioeconomic mixture (predominantly minority to exclusive preparatory school); and locale (small, rural district to large, inner-city district).

Within these diverse institutions, high school science teachers vary widely in their science background (from no significant science course work to graduate degrees in chemistry and physics), and in their desire to participate in self-renewal programs. Given the broad spectrum of situations in which science is taught, are there special windows of opportunity in which the partnerships could have a lasting impact? In particular, would it be effective for the High School-College Research Partnerships program to target women and underrepresented minorities?

Many studies have shown that women and certain minorities (blacks, American Indians, and Hispanics) are greatly underrepresented within scientific fields.[1] The recruitment of students from underrepresented groups is of national importance. It would be commendable if these awards were to have a positive impact on the recruitment and retention of members of these groups.

The initial awards were reasonably successful in involving women high school teachers. Unfortunately, women university faculty members in the sciences are a minority, and there is little chance of improving the situation soon.

The awards were less successful in attracting members of minority groups, either at the high school or collegiate levels. Many of the high schools represented had a diverse mixture of ethnicities, and several were predominantly minority schools. At both conferences the consensus was that the partnership concept should be just as effective for those in minority settings as they are for teachers in majority schools. The participants strongly supported expanded efforts to increase participation of both women and minorities. But they did not feel that programs set aside exclusively for underrepresented groups were advisable at this time.

## Program Prospects and Opportunities

The High School-College Research Partnerships provide an interface between science education at the precollegiate and collegiate levels. During the first year we were able to explore a number of facets of this interface. Most of the original premises of the program were validated, and further opportunities presented themselves. A listing of some of the more promising conclusions and opportunities follows.

**• High School-College Research Partnerships are a two-way street**

The impetus for the establishment of these grants came from the desire to enrich and enhance high school teaching. One of the implicit goals was to establish communication between the two communities, which seldom interact. Research Corporation was optimistic that the benefits to the high school teacher would be immediate and rather specific, and indeed they have been. The partnerships have in many cases also forged a two-way bridge, an avenue for the research scientist to become in-

volved and to contribute to precollegiate science education. The expansion of the partnerships—from a focus on the immediate research to an effort to strengthen science education—is an important and noteworthy consequence of these awards.

**• The partners form a nucleus of experts for future efforts**

It was clear from the conferences that the partners are a core group of qualified, dedicated, and highly committed science educators. The high school teachers were thoughtful and eloquent in their perceptions and expressions of the many issues addressed. The mentors were supportive and receptive to most opportunities to expand the impact of the partnerships. As leaders in their own fields, they form an especially strong core group.

**• The partnerships converge at the crossroads of science education**

The high school teacher is located at a pivotal point in science education. These educators receive the raw material, students whose experience with science has been minimal, and pass them on to the colleges as potential science majors. By keeping in touch with their science, these teachers serve their students well. They are role models, motivators, and mentors. Their classrooms are a good place to intervene, with the prospect of immediate effects at the high school level. An expanded vision also sees the high school teacher as a crucial point in networking with several communities.

**• Developing partnerships is not trivial**

The success of a program that attempts to build bridges between disparate communities requires careful publicity, but that alone is not enough. Each partnership should begin with a meeting between the mentor and the high school teacher. Both should feel comfortable and be optimistic about the prospects of fruitful collaboration. Most of the first-year partnerships involved individuals who had had no previous contact other than this get acquainted session.

Publicity is important not only in the development of partnerships but also after the award has technically ended. High school students and colleagues are impressed by a teacher's linkage to an active research group. It also makes good copy for the local press, and these days science needs every scrap of positive press coverage that it can get. Some of the most effective advertising for the awards will come from former mentors.

*Research Corporation Grants Program Coordinator Brian Andreen chats with research partners at the Los Angeles conference. Experiences were shared and causes charted for the future—"some of the best discussions I've ever been a part of," said one participant.*

**• High school science teachers as mentors**

There is a large task ahead if we are to equip teachers to change perceptions of science during students' early years (K-8). High school teachers can and should be used as mentors, experts in residence. They can present workshops for teachers, give student demonstrations, devise experiments, and act as resource people. Obstacles exist, to be sure. High school teachers are overcommitted, as are pre-secondary school teachers. Nevertheless opportunities can be created to use their expertise and enthusiasm to inspire and equip K-8 teachers.

**• Community colleges: the forgotten segment of higher education**

As Glenn Crosby so ably pointed out in his talk, the community colleges are forgotten by all but the thousands of students who attend them. These institutions enroll 35 percent of U.S. college students. According to one study, most Hispanic and American Indian college students, and half of all black college students, are enrolled in two-year colleges.[2]

Finally, a number of the high school teacher participants also have part-time appointments in community colleges. Efforts to strengthen science education in this country cannot ignore the human resources of the community colleges.

Notes:

1. U.S. Congress, Office of Technology Assessment, *Educating Scientists and Engineers*, Grade School to Graduate School, OTA-SET-377 (Washington, D.C.: U.S. Government Printing Office, June 1988), 52.

2. Ibid.

## Appendices

## Acknowledgments

## *APPENDIX A*

## CONFERENCE PARTICIPANTS

### Los Angeles Conference, Sept. 25, 1988

Brian Andreen, Research Corporation, Ariz.
Bruce A. Barichievich, El Camino High School, Calif.
Rita Barichievich, Crystal Springs Uplands School, Calif.
Victoria Macalalad-Bragin, Mayfield Senior School, Calif.
Jeannette Brown, Merck & Co., Inc./Project SEED (Summer Educational Experience for the Disadvantaged), N.J.
Gerald Caple, Northern Arizona University
William Carpenter, Research Corporation, Ariz.
Anna L. Crabtree, Santa Catalina High School, Calif.
Chris L. Craney, Occidental College, Calif.
Glenn and Jane Crosby, Washington State University
Robin A. DeKleine, Westridge School, Calif.
Joyce Takahashi Doi, University of California, Davis
Peter Farnham, American Society for Biochemistry and Molecular Biology, Md.
Lee A. Flippin, San Francisco State University
Marjorie Gardner, University of California, Berkeley
Eric Gregory, Linden High School, Calif.
Paul Cyrus Groves, South Pasadena High School, Calif.
Robert H. Grubbs, California Institute of Technology
Frank Guthrie, Rose-Hulman Institute of Technology/Indiana Academy of Science
Linda Huetinck, Glendora High School, Calif.
Herbert D. Kaesz, University of California, Los Angeles
Heinz Koch, Ithaca College, N.Y.
William James Layton, Palisades High School, Calif.
David Paul Licata, American Chemical Society, Washington, D.C.
Joan Miller, Solar Energy Research Institute, representing Associated Western Universities, Utah
K. Elaine Miller, Glendale College/Flintridge Prep School, Calif.
Robert Lee Montoya, Yerba Buena High School, Calif.
M. Patricia Noel, Westlake School for Girls, Calif.
John Olmsted III, California State University, Fullerton
Sharon M. Panasenko, Pomona College, Calif.
Donald R. Paulson, California State University, Los Angeles
Dave Ptak, Santa Cruz High School, Calif.
Nuria Rodriguez, Beverly Hills High School
Herbert B. Silber, San Jose State University
Tom Squires, Associated Western Universities, Utah
M. Gloria Sturgeon, University of San Diego High School
Andrew B. Turner, Research Corporation, Ariz.
Trina Valencich, California State University, Los Angeles
Richard Weld, Mayfield Senior School, Calif.
R. Stanley Williams, University of California, Los Angeles
Robert W. Zoellner, Northern Arizona University

### Tucson, Ariz. Conference*, Oct. 14, 1988

Brian Andreen, Research Corporation
David Lawrence Byrum, Flowing Wells Public Schools
Sharon Caple, Tuba City High School
John S. Gallagher III, Lowell Observatory
Victor J. Hruby, University of Arizona
Sheng Hsien Lin, Arizona State University
Jeffrey F. Lockwood, Sahuaro High School
Donald W. McCarthy, Jr., University of Arizona
Myra H. Millinger, The Flinn Foundation
John V. Rund, University of Arizona
John P. Schaefer, Research Corporation
Lynn Schultz, Chandler Senior High School
Timothy C. Steimle, Arizona State University
Grace Sundling, Phoenix Christian High School
Bonnie R. Thompson, Tolleson Union High School
Andrew B. Turner, Research Corporation
Nancy Vosskuhler, North High School
Neville Woolf, University of Arizona
Robert W. Zoellner, Northern Arizona University

*All attendees were from Arizona.

# *APPENDIX B*

## 1988 HIGH SCHOOL-COLLEGE RESEARCH PARTNERSHIPS

### UNIVERSITY OF ARIZONA

**Dan P. Clemens**—Astronomical studies of Bok globules
**James M. Treat, Desert View High School**

**Victor J. Hruby**—Conformational constraints in the development of receptor specific neuropeptides
**Amanda Walton, Tucson High School**

**Donald W. McCarthy, Jr.**—High resolution infrared imaging of low mass companions to nearby stars
**Jeffrey F. Lockwood, Sahuaro High School**

**John V. Rund**—Photochemistry of quadrate chromium(III) complexes
**David Lawrence Byrum, Flowing Wells Public Schools**

### ARIZONA STATE UNIVERSITY

**Sheng Hsien Lin**—Experimental and theoretical investigation of molecular mechanisms of anesthesia
**Grace Sundling, Phoenix Christian High School**

**S. M. Lindsay**—Research in scanning tunneling microscopy
**Lynn Schultz, Chandler Senior High School**

**Timothy C. Steimle**—Laser-RF studies of transition metal aggregates
**Nancy Vosskuhler, North High School**

### UNIVERSITY OF CALIFORNIA, BERKELEY

**Stuart Bowyer**—The Berkeley Piggyback SETI (Search for Extraterrestrial Intelligence) Program: SERENDIP II
**Tucker Hiatt, San Francisco University High School**

### UNIVERSITY OF CALIFORNIA, DAVIS

**Joyce Takahashi Doi**—Cyclic and acyclic mixed anhydride models for phosphate or sulfate transfer
**Eric Gregory, Linden High School**

### UNIVERSITY OF CALIFORNIA, LOS ANGELES

**Herbert D. Kaesz**—Organometallic chemical vapor deposition (OMCVD) of transition metals
**M. Patricia Noel, Westlake School for Girls**

**Matthew A. Malkan**—Near infrared spectrophotometry of bright quasars
**Nuria Rodriguez, Beverly Hills High School**

**R. Stanley Williams**—Surface studies of metals and semiconductors using the scanning tunneling microscope
**Linda Huetinck, Glendora High School**

### UNIVERSITY OF CALIFORNIA, SAN DIEGO

**Kurt Marti**—Nitrogen isotopic abundances in the Acapulco meteorite
**M. Gloria Sturgeon, University of San Diego High School**

### UNIVERSITY OF CALIFORNIA, SANTA CRUZ

**Phillip Crews**—Investigation of the cytotoxicity, conformational properties, and ionophoric selectivity of Jasplakinolide and its derivatives
**Anna L. Crabtree, Santa Catalina High School**

### CALIFORNIA STATE UNIVERSITY, FULLERTON

**John Olmsted III**—Synthesis and photophysical studies of polystyrene doped with sensitizer and charge-trapping sites
**Carole J. Seifert, La Quinta High School**

### CALIFORNIA STATE UNIVERSITY, LOS ANGELES

**Donald R. Paulson**—Metallo-sulfur complexes as models for electron transfer proteins
**K. Elaine Miller, Glendale College and Flintridge Prep School**

**Trina Valencich**—Reaction path orientation dependence
**Victoria Macalalad-Bragin, Mayfield Senior School**

### CALIFORNIA INSTITUTE OF TECHNOLOGY

**David L. Goodstein**—High temperature superconductivity
**William J. Layton, Palisades High School**

**Robert H. Grubbs**—Computational approaches to polymer structures
**Paul Cyrus Groves, South Pasadena High School**

### LOWELL OBSERVATORY

**Edward Bowell**—Astrometry and photometry of asteroids
**Kenneth W. Zeigler, Globe High School**

**John S. Gallagher III**—A survey of galactic novae
**Wayne Williams, Corona del Sol High School**

### MONTEREY INSTITUTE FOR RESEARCH IN ASTRONOMY

**William Bruce Weaver**—Spectrophotometry of high galactic latitude IRAS objects
**Virginia A. Esmond-Badger, Gilroy Unified School District**

### UNIVERSITY OF NEW MEXICO

**Ulrich Hollstein**—Isolation and structure of antigonadotropins from *Lithospermum*
**Patricia Alexander Jones, Highland High School**

**NEW MEXICO STATE UNIVERSITY**

**Alan Van Heuvelen**—Evaluation of implantable blood glucose monitoring device
**Stephen Kanim**, Las Cruces High School

**NORTHERN ARIZONA UNIVERSITY**

**Gerald Caple**—Organic semiconductor based biosensors
**Sharon Caple**, Tuba City High School

**Robert W. Zoellner**—Ammonia and amine complexes of transition metals prepared by metal vapor synthesis techniques
**Bonnie R. Thompson**, Tolleson Union High School

**OCCIDENTAL COLLEGE**

**Chris L. Craney**—Synthesis and isolation of $^{14}C$ NADP for subsequent studies of human glucose-6-phosphate dehydrogenase
**Richard Weld**, Mayfield Senior School

**UNIVERSITY OF THE PACIFIC**

**Michael J. Minch**—NMR studies of polyamine binding to DNA-hydrophobic and ion competition effects
**Mary Kay Sciarani**, Lincoln High School

**POMONA COLLEGE**

**Sharon M. Panasenko**—Structural characterization of LPS from *M. xanthus*
**Robin DeKleine**, Westridge School

**SAN FRANCISCO STATE UNIVERSITY**

**Lee A. Flippin**—Isolation and characterization of the Cyclodepsipeptide complex CDPC 3510 from *Fusarium tricinctum* NRRL 3510
**Rita Barichievich**, Crystal Springs Uplands School

**F. Ann Walker**—Synthesis and spectroscopic properties of atropisomeric porphyrin complexes of low-spin iron(III)
**Bruce A. Barichievich**, El Camino High School

**SAN JOSE STATE UNIVERSITY**

**J. V. Acrivos**—Study of intercalated superconducting perovskites
**Dave Ptak**, Santa Cruz High School

**Herbert B. Silber**—Lanthanide complexation reactions
**Robert Lee Montoya**, Yerba Buena High School



## *APPENDIX C*

### PROGRAM GUIDELINES - 1988

### HIGH SCHOOL-COLLEGE RESEARCH PARTNERSHIPS

Research is the frontier of science through which new discoveries and explanations of nature arise. The development of new technologies depends heavily upon both basic and applied research.

At the heart of scientific discovery and advancement is basic research, the cornerstone of graduate education in the sciences. Even many undergraduates participate in a hands-on research experience under the guidance of faculty mentors. While most high school students will not participate in a research program, it is important that they learn something about how research is carried out before they reach college, whether or not they eventually become scientists.

Unfortunately, high school teachers have usually been educated in a system which emphasizes the transmittal of textbook knowledge without a research component. As a result, they have little appreciation of how science moves forward through research, and are unable to convey a sense of this process and the excitement of discovery to their students. Direct research experiences—which can vitalize classroom teaching—are usually not available.

#### Summer Research Participation

As an experimental undertaking, Research Corporation will make awards to college and university scientists to enable high school science teachers to participate in research during the summer. Applications will be accepted from eligible college or university faculty members at institutions in Arizona, California, and New Mexico. Each award recipient will serve as a mentor to a high school physics or chemistry teacher engaged in a summer research experience.

Teacher participation in work at the cutting edge of science is a primary goal of the research partnerships. Communication between the teachers and academic scientists also represents an opportunity for professional growth. Secondary goals are to establish greater interest in high school science teaching, to help teachers guide able students toward careers in science, and to foster long-term collaboration.

### Eligibility

There are no restrictions with regard to the college mentor's age, rank, or length of service. To apply, however, investigators must:

1. Be former or current Research Corporation grantees
2. Have active research programs
3. Hold appointments in chemistry or physics departments at institutions in Arizona, California, or New Mexico granting at least four-year baccalaureate degrees
4. Make arrangements with appropriate high school teachers

High school teachers should possess academic qualifications in the appropriate disciplines.

### Budgets

Each award will be in the amount of $5,000 per summer (proposals for two summers of support will be considered). Up to $3,500 may be used as a stipend for the high school teacher with the balance available for discretionary income.

### Applications

Prospective applicants should submit to the Grants Program Coordinator a short letter which includes:

1. A brief description of the research that will be conducted
2. The name, affiliation, and background of the high school faculty participant
3. A statement on how the collaboration will contribute to both the high school and collegiate programs

Further instructions and application forms will be provided to those investigators who meet the criteria. Applications must be submitted and endorsed by the applicant's institution. They will be accepted beginning in September, with a deadline of November 1.

### Review Process

Completed applications will be reviewed by the Research Corporation staff, with notification of awards normally made on or about February 1. Address correspondence and inquiries to:

Brian Andreen
Grants Program Coordinator
Research Corporation
6840 East Broadway Boulevard
Tucson, Arizona 85710-2815

Telephone (602) 296-6771

### Other Programs

The Cottrell College Science Grants fund research with undergraduates in predominantly undergraduate college and university departments. These awards are focused on research in astronomy, chemistry, physics, and related areas in the life sciences. Detailed guidelines are available.

The Research Opportunity Awards are for mid-career and senior scientists of demonstrated productivity and creativity seeking to explore new areas of experimental research. One nomination annually is invited from the chair of each Ph.D.-granting physics and chemistry department in the United States. More information is available from the program guidelines.

Research Corporation maintains a continuing interest in the natural sciences at colleges and universities. The foundation welcomes requests for support of any unusual, challenging ideas or programs with high potential for the advancement of science. Prior to submitting a formal proposal, a prospective applicant should prepare a brief preliminary letter outlining the idea. An estimate of the required budget should be included. Formal applications will be invited from those with proposals that appear promising.

From time to time new initiatives or programs will be launched by the foundation that address areas of special opportunity. Summaries of programs current at any time can be obtained from the Grants Program office in Tucson, and are published regularly in Research Corporation reports and newsletters.

**Acknowledgments**

Research Corporation last funded high school science programs in the 1950s. To assist in the formation of the foundation's newest venture, the High School-College Research Partnerships, we relied heavily upon advice of those who have developed similar programs.

Especially helpful were Marjorie Gardner, Lawrence Hall of Science; and Peter Farnham, American Society for Biochemistry and Molecular Biology. Dr. Gardner and Mr. Farnham shared freely of their experience and expertise with openness and candor. David Licata of the American Chemical Society and Jack Wilson of the American Association of Physics Teachers were also instrumental in publicizing the program.

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Chevron USA, Inc.

The Flinn Foundation

Pacific Telesis Foundation

Syntex Corporation

The High School-College Research Partnerships are now in their second year, and interest remains high. Research Corporation encourages other organizations to consider similar programs and will gladly share any new insights or evaluations with interested parties. New and revised guidelines are in effect for the current program. Please address further inquiries on this program to Brian Andreen, Grants Program Coordinator, Research Corporation, 6840 East Broadway Boulevard, Tucson, Arizona 85710-2815 (Tel. 602/296-6771).

W. Stevenson Bacon, Director of Communications
Patricia Belbey, Editorial Assistant

Compilation and general sections by Jill Goetz

Cover Design: Rebecca Gaver

Photographs:
Page 4 - Lori Stiles, University of Arizona; Page 5 (top) - Bonnie Thompson, Tolleson Union High School; (bottom) - Victoria Macalalad-Bragin, Mayfield Senior School; Page 6 - Robert Montoya, Yerba Buena High School; Page 7 - Lori Stiles, University of Arizona; Page 8 (top) - Lori Stiles, University of Arizona; (bottom) - Sheng Hsien Lin, Arizona State University; Page 9 - Research Corporation; Page 11 - Washington State University; Page 12 - MMT Observatory; Page 13 - Jeffrey Lockwood, Sahuaro High School; Page 14 - Victoria Macalalad-Bragin, Mayfield Senior School; Page 15 - Herbert Kaesz, University of California-Los Angeles; Page 16 - Research Corporation; Page 18 - *Monterey Peninsula Herald*; Page 19 - Research Corporation; Pages 20-22, 24 - Andrew B. Turner, Research Corporation.